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ANNUAL REPORT

BORON

By Phyllis A. Lyday

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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ANNUAL REPORT

BORON

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

September 1991

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COVER PHOTO:
Kernite, a boron-rich mineral, was discovered in 1925 in a large borate deposit in the Mojave Desert, CA. First called rasorite, the mineral was later named kernite, after Kern County. (Photo is courtesy of United States Borax & Chemical Corp.)

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BORON

By Phyllis A. Lyday

Mrs. Lyday has covered boron for 12 years. Domestic survey data were prepared by Rosa McGee, mineral data assistant; and international data were prepared by Harold Willis, international data coordinator.

U.S. production and sales of boron minerals and chemicals increased during the year. Domestically, glass fiber insulation was the largest use for borates, followed by sales to distributors, textile-grade glass fibers, and borosilicate glasses.

California was the only domestic source of boron minerals. The United States continued to provide essentially all of its own supply while maintaining a strong position as a source of sodium borate products and boric acid exported to foreign markets.

Supplementary U.S. imports of Turkish calcium borate and calcium-sodium borate ores, borax, and boric acid, primarily for various glass uses, continued.

DOMESTIC DATA COVERAGE

Domestic data for boron are developed by the U.S. Bureau of Mines from two separate, voluntary surveys of U.S. operations. Of the three operations to which a sold and used survey request was sent, all responded, representing 100% of the total boron sold or used shown in tables 1 and 9. A Bureau canvass of the three U.S. producers also collected data on domestic consumption of boron minerals and compounds shown in tables 4 and 5.

BACKGROUND

Definitions, Grades, and Specifications

Few of the many minerals that contain boron are commercially valuable. Only colemanite and ulexite minerals, primarily imported from Turkey, are marketed in the United States. The boron oxide content of both minerals is usually marketed at about 40%.

Tincal and kernite ore and brines are the U.S. source of refined borate chemical compounds. The most common refined borates, borax pentahydrate and its derivative anhydrous borax, are marketed in technical and agricultural grades. Lesser quantities of borax decahydrate are produced in technical, United States Pharmacopeia, and special quality grades.

Boric acid is a white, odorless, crystalline solid sold in technical national formulary and special quality grades as granules or powder. Boron oxide is a

TABLE 1

SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS

(Thousand metric tons and thousand dollars)

	1986	1987	1988	1989	1990
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[1]	1,135	1,256	1,149	1,114	1,094
Boron oxide (B_2O_3) content	571	625	578	562	608
Value	$426,086	$475,092	$429,667	$429,806	$436,176
Exports:					
Boric acid:[2]					
Quantity	38	61	56	42	39
Value	$23,562	$34,180	$35,301	$32,613	$31,679
Sodium borates:					
Quantity[3]	566	552	546	646	585
Value[e]	$161,000	$243,600	$240,800	$361,000	$208,433
Imports for consumption:[4]					
Boric acid:					
Quantity	5	2	3	3	6
Value	$3,824	$2,900	$2,020	$2,197	$3,291
Colemanite:					
Quantity	15	7	17	15	12
Value	$8,770	$2,763	$7,790	$4,202	$3,310
Ulexite:					
Quantity	38	47	31	27	29
Value	$17,766	$20,597	$7,480	$1,552	$7,360
Consumption: Boron oxide (B_2O_3) content	307	335	356	315	319
World: Production	r2,511	r2,684	r2,924	r2,926	e2,906

e Estimated. r Revised.

[1] Minerals and compounds sold or used by producers, including both actual mine production and marketable products.

[2] Includes orthoboric and anhydrous boric acid.

[3] The Journal of Commerce Port Import/Export Reporting Service.

[4] Boron oxide (B_2O_3) content. In addition, borax imports from Turkey were 4,356 tons in 1987, 8,165 tons in 1988, 7,257 tons in 1989, and 5,162 tons in 1990.

TABLE 2

BORON MINERALS OF COMMERCIAL IMPORTANCE[1]

Mineral	Chemical composition	B_2O_3 weight percent
Boracite (stassfurite)	$Mg_6B_{14}O_{26}Cl_2$	62.2
Colemanite	$Ca_2B_6O_{11}{\cdot}5H_2O$	50.8
Hydroboracite	$CaMgB_6O_{11}{\cdot}6H_2O$	50.5
Kernite (rasorite)	$Na_2B_4O_7{\cdot}4H_2O$	51.0
Priceite (pandermite)	$Ca_5B_{12}O_{23}{\cdot}9H_2O$	49.8
Probertite (kramerite)	$NaCaB_5O_9$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.4
Szaibelyite (ascharite)	$MgBO_2(OH)$	41.4
Tincal (natural borax)	$Na_2B_4O_7{\cdot}10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O{\cdot}5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9{\cdot}8H_2O$	43.0

[1] Parentheses include common names.

hard, brittle, colorless solid resembling glass that is ground and marketed most often under the name anhydrous boric acid.

Elemental boron is a dark-brown powder in the amorphous form and a yellowish-brown, hard, brittle solid in the monoclinic crystalline form. Boron is marketed in grades from 90% to 99% purity.

Ferroboron is a name given to a variety of boron-iron alloys containing 0.2% to 24% boron used primarily to introduce small quantities of boron into specialty steels.

In the boron hydride series of compounds are diborane, a gas; pentaborane, a liquid; and decaborane, a solid. These compounds have been studied as fuels that range from 31,220 British thermal units (Btu) per pound for diborane to 27,850 Btu per pound for decaborane. Sodium borohydride is marketed in powder or pellet form and in sodium hydroxide solution.

Boron nitride, a soft, white, highly refractory solid resembling graphite, can withstand significant oxidation temperatures up to 650° C. Boron nitride produced in fibrous form equals glass fibers in strength and modules of elasticity, but is lighter in weight and more resistant to high temperature. When subjected to extremely high pressure and temperature, boron nitride forms cubic crystals that rival the hardness of diamond.

Boron carbide, produced by reacting carbon and boric acid at 22,600° C, is a highly refractory material and one of the hardest substances known. Most commonly used for both abrasive and abrasion-resistant applications as well as nuclear shielding, boron carbide is marketed in technical and high-purity grades.

Byproducts and Coproducts

More than four-fifths of the U.S. production comes from mineral deposits mined only for their boron content. The remainder is produced from lake brines, which also supply sodium carbonate, sodium sulfate, potassium sulfate, and potassium chloride. Turkish colemanite, ulexite, and tincal ores are worked only for their boron content. Most Soviet borates are also mined only for their boron content, but the Gulf of Kara-Bagaz-Gol and the Sivash (lagoon) borates are extracted with coproduct chloromagnesium from brines. South American boron has been mined from ores and also has been produced as a coproduct of nitrate and iodine production.

Economic Factors

Costs.—Energy costs are especially high for producing anhydrous products. The anhydrous products were originally introduced to decrease freight costs per ton of contained boron oxide. Both domestic producers now use cogeneration facilities to reduce the cost of energy for processing and supplying excess electricity for sale.

Depletion Provisions.—The domestic and foreign depletion allowances for boron are 14% of gross income and may not exceed 50% of net income without the depletion deduction.

Operating Factors

Naturally occurring boron compounds have relatively low toxicity for man and other mammals. Sodium borates, boric acid, and boron oxide are not present to any significant degree in air and are placed in the same hazard category as general dust. Ingestion in quantities greater than 20 grams by an adult can cause nausea and skin rashes.

Small quantities of boron are essential for all plant life. Boron is added in trace levels to fertilizers; however, quantities well below concentrations affecting man and animals are so extremely toxic to vegetation that boron compounds are also used commercially as herbicides. Concentrated boric acid is used to control certain insects and in dilute solutions as a preservative to control the growth of bacteria.

TABLE 3

TIME-PRICE RELATIONSHIPS FOR BORAX PENTAHYDRATE[1]

Year	Average annual U.S. producer price, dollars per metric ton
	Actual prices
1971	83
1972	83
1973	88
1974	108
1975	116
1976	121
1977	130
1978	141
1979	184
1980	186
1981	205
1982	222
1983	222
1984	229
1985	236
1986	243
1987	249
1988	249
1989	259
1990	249

[1] Borax pentahydrate, technical, granular, 99.5%, bulk, carlots, works.

ANNUAL REVIEW

Legislation and Government Programs

The Office of Foreign Availability (OFA), Department of Commerce, Bureau of Export Administration, requested comments in the October 23 issue of the Federal Register on the foreign availability of pyrolytic boron nitrite worldwide. On July 30, 1990, OFA accepted for filing a foreign availability submission relating to the decontrol of pyrolytic boron nitride crucibles, boats, furnace tubes, liner, and other specially designed shapes used in the manufacture of semiconductor devices and integrated circuits to controlled countries. The submission period for comments was to close November 23.

The desert tortoise was designated an endangered species by the Fish and Wildlife Service (FWS) of the U.S. Department of the Interior. About 500 plants and animals are now protected by the 1973 Act. By law, FWS looks only at scientific facts as to whether further pressure will lead to extinction.[1] The FWS cited habitat deterioration and loss, disease, and varied human uses of the desert as some of the principal threats facing the tortoise. Energy and mineral development were listed as one of the land uses affecting the tortoise. The listing extends long-term protection to tortoises living north and west of the Colorado River, including eastern California, southern Nevada, northwestern Arizona, and southwestern Utah. The areas listed include boron areas being surface mined and a solution-mining project area. Any change in land use in these areas require consultation with the FWS beforehand.

Congress continued discussion and debate over whether there should be changes to the Mining Law of 1872, better known as the General Mining Law. Sodium borate minerals, which are excluded from the law, are included under the Mineral Leasing Act of 1920, as amended and supplemented.

The Bureau continued two ongoing studies dealing with Federal land availability in the California Desert Conservation Area (CDCA). The CDCA contains all commercial domestic deposits of boron minerals and most of the known reserves. One Bureau study is site specific and the other deals with Federal land availability. The first study will examine in detail about 10 selected known deposits and active mines in the CDCA. In the second study, the Bureau will show how Federal land practices and withdrawals affect known mineral deposit areas in the CDCA.[2]

The U.S. Bureau of Mines, Division of Policy Analysis, completed an investigation of the East Mojave National Scenic Area, CA. The report was available as a Mineral Land Assessment open file in two volumes from the U.S. Bureau of Mines. Volume one is resource information, and volume two is related economics.

The Bureau of Land Management issued a new policy that mandates reclamation bonding on all mining and exploration plans of operation involving 5 acres or more of land. The policy applies for all new operations.[3]

A $9 million plan to develop maglev systems was introduced into Congress as part of the U.S. Department of Transportation budget. Maglev transportation systems consist of a train-like vehicle riding several inches above a metal guideway on a magnetic field at speeds of up to 400 miles per hour. Currently, there are proposed systems connecting southern California with Las Vegas, NV, and a local system in Las Vegas that uses boron magnets.[4]

Production

The majority of the boron production continued to be from Kern County, with the balance from San Bernardino and Inyo Counties, CA.

American Borate Co., a wholly owned subsidiary of Owens-Corning Fiberglas Corp., continued sales of ulexite from storage at Dunn, CA.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. At the Trona plant, a differential evaporative process produced borax with potash as a byproduct. Boric acid was produced by solvent extraction. The Westend plant continued production of sodium borates by a carbonation process. Brines used in the process were pumped to the Argus plant to produce sodium sulfate.

At yearend, three chemical processing facilities, of which two produce boron compounds, and the Trona Railway were sold for $210 million to an investment group led by D. George Harris & Associates. The organization will be known as North American Chemical Co. with a base of operations in Kansas City, MO. The investment group includes Oriental Chemical Industries of Korea and Chase Manhattan Investment Holdings Inc. Oriental Chemical will represent North American for certain product lines sold in the Far East.

United States Borax & Chemical Corp., a part of Borax Consolidated Ltd. of the RTZ Corp. PLC of London, United Kingdom, continued to be the primary world supplier of sodium borates.

U.S. Borax mined and processed crude and refined sodium borates, their anhydrous derivatives, and anhydrous boric acid at Boron, in Kern County, CA. A second plant at Boron used a proprietary process to produce technical-grade boric acid from extensive kernite ore reserves. The boric acid was produced to compete with imported colemanite used in glass manufacture. In addition, colemanite was mined at Shoshone, in Inyo County, CA.

The majority of material was shipped to Wilmington, CA. Products made at a plant in Wilmington included ammonium borates, potassium borates, sodium metaborates, and zinc borate. Corona Corp. continued ownership of the Fort Cady Minerals Corp., but construction of a boric acid plant was delayed by environmental assessment studies of mining and reclamation plans that were necessary to receive permits. The agreement between Corona and Avalon Corp. to acquire the Fort Cady Minerals Corp. was terminated.[5]

Consumption and Uses

U.S. consumption of borates increased. Glass fiber insulation and glass fiber primarily used as reinforcement for plastics continued to be the largest consuming industries.

The use of borates in glass fiber thermal insulation, primarily used in new construction, was the largest area of demand for borates. Cellulosic insulation, the seventh largest area of demand, decreased.

The second major market for borates, manufacturing high-tensile strength glass fiber materials for use in a range of products, showed an increase in

demand. The nonconductive and low dielectric properties of high-strength glass-reinforced materials make them transparent to radar and thus valuable for "stealth" applications. Carbon-fiber-reinforced resins can be stronger than metals and, with higher modules, more dimensionally stable. Although composites can be 10 times more expensive than typical aerospace-grade aluminum, the flexibility they offer in design and consolidation of parts allows large, complex structures to be fabricated to exacting specifications. In addition, their light weight and ability to withstand high temperatures have made composites the material of choice for a variety of aerospace applications.

In advance composites, carbon, higher module glasses, and aramid fibers account for about 95% of the market; glass accounts for about 20% of the market. At $200 to $500 per pound, less than 1% of the market is specialty fibers, such as boron, silicon carbide, and quartz. In advanced composites, fibers generally make up 60% of the material by volume.[6]

The Bradley Fighting Vehicle is a new fiberglass composite weapon that faced combat for the first time in the Persian Gulf. Because of an invasion of Kuwait by Iraqi forces, troops and equipment, including the Bradley, were transported to Saudi Arabia. The Bradley is produced by FMC Corp. at San Jose, CA, for the U.S. Army. More than 5,249 Bradleys were delivered by yearend.[7]

Consumption of borates in borosilicate glasses remained the third major end use, and demand decreased. Boron added to glass reduced the viscosity of the melt, assisted with fiber formation during processing, and allowed for thermal expansion of the product.

Boron compounds in cleaning and bleaching were the fourth major end use. Oxygen systems, such as peroxygens, including perborates, may replace chlorine-base bleach systems because they are less harsh on fabric. Demand for monohydrate was reported to have doubled between 1987 and 1989. Sodium perborate is a solid peroxygen bleach used in powder detergents. Consumption of the monohydrate was reported to be in excess of 40,000 tons during 1990.[8] E. I. du Pont de Nemours & Co. Inc. planned to become the first domestic producer of a solid peroxygen bleaching chemical. The plant, in Memphis, TN, planned to be operational during 1991.[9] Interox America announced the construction of a 45-million-pound monohydrate plant at Deer Park, TX. The planned startup date was to be early in 1992.

Boron compounds continued to find application in the manufacture of biological growth control chemicals for use in water treatment, algicide, fertilizers, herbicides, and insecticides. Boron can be applied as a spray or incorporated in herbicides, fertilizers, and irrigation water. Commercial Fertilizers magazine reported that total fertilizer consumed between June 30, 1989, and June 30, 1990, as boron compounds amounted to about 7,000 tons used in five regions. Only a small amount of boron is required on alfalfa, clover, and vegetables to promote optimum growth and yields.[10]

Boron compounds were also used in metallurgical processes as fluxes, shielding slag in the nonferrous metallurgical industry, and components in electroplating baths. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and specialty steels, respectively.

Boron carbide and boron nitride are two exclusively manufactured materials synthesized by the reaction of boron oxide with other materials.[11] These products are consumed as abrasives, cutting tips, blasting nozzles, nuclear control rods, and various other uses. A market study by Mitchell Market Reports of Gwent, United Kingdom, contained approximately 300 companies in 20 countries that produce, use, or consume boron carbide and boron nitride.

SB Chemical Ltd., a refiner and manufacturer of elemental boron in Franklin Park, IL, changed names to SB Boron Corp. The company is the sole producer of elemental amorphous boron powder in 90% to 92% (pyrotechnic) and 95% to 97% (aerospace) grades.[12]

Prices

Prices for anhydrous-, pentahydrate-, and decahydrate borax and technical boric acid remained essentially at 1989 levels. Other prices, including high-purity boric acid and colemanite, increased.

Foreign Trade

The majority of material from the U.S. Borax facility in Boron was shipped to storage, loading, and ship-

TABLE 4

U.S. CONSUMPTION OF BORON MINERALS AND COMPOUNDS, BY END USE[1]

(Metric tons of boron oxide content)

End use	1989	1990
Agriculture	14,583	5,787
Borosilicate glasses	30,600	27,905
Enamels, frits, glazes	8,149	7,882
Fire retardants:		
Cellulosic insulation	11,920	11,741
Other	509	1,401
Glass-fiber insulation	91,736	95,059
Metallurgy	3,040	2,554
Miscellaneous uses	14,729	14,586
Nuclear applications	611	546
Soaps and detergents	25,145	24,230
Sold to distributors, end use unknown	73,460	71,670
Textile-grade glass fibers	40,499	55,698
Total	314,981	319,059

[1] Includes imports of borax, boric acid, colemanite, and ulexite.

TABLE 5

U.S. CONSUMPTION OF ORTHOBORIC ACID, BY END USE[1]

(Metric tons of boron oxide content)

End use	1989	1990
Agriculture	231	108
Borosilicate glasses	4,862	4,920
Enamels, frits, glazes	1,383	1,013
Fire retardants:		
Cellulosic insulation	1,683	1,647
Other	509	1,401
Insulation-grade glass fibers	1,081	1,682
Metallurgy	278	393
Miscellaneous uses	9,779	8,948
Nuclear applications	494	544
Soaps and detergents	57	50
Sold to distributors, end use unknown	23,379	24,204
Textile-grade glass fibers	22,493	19,482
Total	66,229	64,392

[1] Includes imports.

ping facilities at Wilmington, CA. A large part of output was exported to Western Europe from Wilmington to Botlek, Netherlands.

World Review

Capacity.—The data in table 9 are rated capacity for mines and refineries as of December 31, 1990. Mine capacity for boron was based on rated capacity as reported by the company, by another government agency, or another published source. Capacity outside of the United States was limited by the availability of loading and transportation equipment and market demand rather than limitations of ore grade.

Argentina.—Boroquimica S.A.M.I.C.A.F., a subsidiary of RTZ, continued production of tincal and boric acid from a deposit at Tincalayu, Salta Province.

Belgium.—Degussa Corp. planned to add sodium perborate monohydrate capacity at its Antwerp, Belgium, facility while hydrogen peroxide capacity is expanded. Degussa now makes perborate tetrahydrate, which is used in solid detergents. The trend in Europe is toward liquid detergents using the monohydrate.[13]

Bolivia.—Beginning in August 1987, the United Nations Development Program (UNDP) provided considerable assistance to Bolivia in the assessment of nonmetallic resources. A U.N. Revolving Fund of $1.3 million drilling program began to investigate the economic potential of known and possible mineral resources in Bolivia. Lithium Corp. of America (Lithco) signed a preliminary contract November 17, 1989, for development of Salar de Uyuni, which is reported to contain the world's richest reserves of lithium salts and 3.2 million tons of boron minerals. On May 4, the $46 million contact with Lithco was canceled, and the project was opened for international bidding.[14] During 1989, the Government reported that 10,000 metric tons of ulexite was exported.[15]

Chile.—At yearend, AMAX Exploration Inc. was seeking partners to purchase its 65.5% stake in the Sociedad Minera Salar de Atacama Ltda. (Minsal) project. The feasibility study included the development of a 22,000-ton-per-year boric acid plant at the Salar de Atacama. The salar is one of about 74 arid salt basins in the Chile-Bolivia-Argentina border region. At capacity, the project will also produce 533,000 tons per year of potassium chloride, 276,000 tons of potassium sulfate, up to 35 million pounds of lithium carbonate, and 5 million pounds of lithium hydroxides. The availability of more than 1 million tons per year of sulfuric acid from the Chiquicamat copper smelter will enhance the economic viability of the project.[16]

In 1988, production of ulexite and boric acid was estimated at 35,000 tons per year from salt deposits in the north. Quimica e Industrial del Borax Ltda. (Quiborax) is the main producer of boric acid and concentrated ulexite. Minera del Boro, Minera Ascotan, and Boroquimica are smaller local producers. Quiborax and Minera del Boro planned capacity increases. By 1994, Minsal planned to have completed a boric acid expansion of 18,000 tons per year.[17]

France.—Atochem Inc., a member of the Elf Aquitaine Group, planned a 13,000-ton-per-year sodium perborate monohydrate plant at Pierre Benite, near Lyon, to be operational in 1991.[18] The company already operates a 48,000-ton-per-year plant at the same location for sodium perborate tetrahydrate, the starting material for the monohydrate form. Both hydrates are used as whitening additives in domestic detergents.[19] Atochem has also announced plans to build a monohydrate plant at Warrington, United Kingdom, and convert production from tetrahydrate to monohydrate at sites in Belgium, the Federal Republic of Germany, and Italy.[20]

Cie. de St. Gobain signed an agreement to acquire Norton Co. of Worcester, MA, a producer of boron carbide. St. Gobain is a leading producer of glass products and owns CetainTeed Corp.[21]

India.—The Ministry of Agriculture brought boron-enriched single superphosphate (SSP) under the Fertilizer Control Order to ensure greater benefits and better quality fertilizer in micronutrient-deficient areas. Dharamsi Morarji Chemicals has been asked to resume the production of boron-enriched SSP, a slow-release fertilizer. Maharastra and Gujarat Pradeshes are under intense cotton cultivation and suffer from boron deficiency.[22]

TABLE 6

YEAREND 1990 PRICES FOR BORON MINERALS AND COMPOUNDS[1]

(Per metric ton)

Product	Price, December 31, 1990 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carload, works[2]	719
Borax, technical, anhydrous, 99%, bags, carload, works[2]	761–769
Borax, technical, granular, decahydrate, 99.5%, bags, carload, works[2]	285–418
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[2]	236
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[2]	321
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works[2]	272
Boric acid, technical, granular, 99.9%, bags, carload, works[2]	775–784
Boric acid, technical, granular, 99.9%, bulk, carload, works[2]	725–726
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound bags, carlot	2,849
Colemanite, Turkish, 40% to 42% B_2O_3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC[3]	507
Ulexite, Turkish, 37% B_2O_3, ground to a minus 100-Mesh, f.o.b railcars, Norfolk, VA.[3]	230

[1]U.S. f.o.b. plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.
[2]Chemical Marketing Reporter. V. 238, No. 27, Dec. 1990, p. 25.
[3]American Borates Co.

Peru.—Throughout 1989, all companies in the mining sector, regardless of size, faced the problems brought on by high inflation and an unfavorable exchange rate. High interest rates and payroll increases led the rise in local costs, while the rise in revenues lagged behind costs because the depreciation of the currency failed to keep pace with inflation. The exchange rate applied to exporters, including miners, meant export receipts were exchanged at an average of only 74% of the free market exchange rate. Labor problems were less significant to production than in 1988, although terrorists increased their activities, causing loss of lives and important material damages.[23]

Taiwan.—PPG Industries Inc. jointly owns a 20,000-ton-per-year fiberglass plant operated by PFG Fibre Glass Corp. in a joint venture with Nan Ya Plastics, a business of Formosa Plastics Group.[24]

Turkey.—Turkey's boron operations are under the control of the Government corporation, Etibank, that mines boron from major deposits at Bigadic, Kirka, and Emet. Etibank operates refining facilities to produce refined sodium borates and boric acid from tincal concentrates at Bandirma. Boron minerals and compounds are shipped from the Port of Bandirma on the Sea of Marmara and Izmir on the Aegean Sea.

United Kingdom.—Pilkington Special Glass Ltd. closed a special glass plant producing nuclear shielding and electronics in St. Asaph, Clwyd, North Wales, with the loss of 140 jobs. The operation will continue to employ 190 people who manufacture high index ophthalmic and photochromic glass blanks using boron.[25]

Venezuela.—PPG Industries Inc. (49%), Pittsburgh, PA, and the Sudamtex Group of Caracas began operation of a plant to produce continuous strand fiberglass at Barcelona operated by the Sudamtex subsidiary VFG-Sudamtex (51%). The company is the only fiberglass producer in the Andean Pact countries (Bolivia, Colombia, Ecuador, Peru, and Venezuela).[26]

TABLE 7

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY

Country	1989			1990		
	Boric acid[1]		Sodium borates[2]	Boric acid[1]		Sodium borates[2]
	Quantity (metric tons)	Value (thousands)	(metric tons)	Quantity (metric tons)	Value (thousands)	(metric tons)
Argentina	—	—	2			
Australia	1,338	$982	8,271	967	$729	7,401
Bangladish	—	—	168	—	—	32
Belgium-Luxembourg	—	—	1,290	—	—	425
Brazil	141	133	2,831	113	89	2,126
Canada	4,822	2,927	50,966	5,682	3,500	41,929
Chile	1	2	1,310	—	—	
China	—	—	8	—	—	175
Colombia	237	132	1,241	137	109	3,837
Costa Rica	17	15	90	—	—	2,593
Dominican Republic	128	20	37	374	203	11
Ecuador	—	—	847	—	—	1,119
Egypt	—	—	1,380	—	—	
El Salvador	—	—	5	—	—	24
Finland	—	—	—	244	144	199
France	—	—	222	88	44	1,224
Germany, Federal Republic of	313	138	12	119	88	92
Guatemala	28	17	39	1,466	562	82
Haiti	20	2	130	—	—	224
Honduras	—	—	82	46	16	41
Hong Kong	270	199	3,536	253	263	2,984
India	26	10	6,593	—	—	
Indonesia	380	279	5,681	256	205	7,450
Israel	87	65	168	104	93	290
Jamaica	3	6	5	2	6	10
Japan	20,270	15,512	46,593	15,999	12,875	39,064
Korea, Republic of	1,863	1,563	15,651	1,472	1,238	19,200
Malaysia	56	48	5,645	154	113	7,268
Mexico	2,662	1,824	23,187	2,282	1,622	24,531
Netherlands	3,647	4,620	404,474	4,382	5,823	349,968
New Zealand	1,363	857	2,817	485	350	3,040
Pakistan	—	—	152	—	—	409
Panama	24	14	28	2	8	79
Papua New Guinea	32	24	32	—	—	80
Peru	57	22	92	3	3	18
Philippines	135	108	1,933	—	—	2,075
Romania	—	—	—	—	—	
Saudi Arabia	42	30	389	31	44	22
Singapore	62	40	1,507	261	195	1,920
South Africa, Republic of	65	58	1,751	47	52	1,762
Spain	—	—	35,642	202	126	43,345
Sri Lanka	9	7	16	—	—	
Taiwan	3,082	2,332	17,561	2,962	2,390	15,291
Thailand	400	329	2,267	544	457	2,380

See footnotes at end of table.

TABLE 7—Continued

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY

Country	1989			1990		
	Boric acid[1]		Sodium borates[2]	Boric acid[1]		Sodium borates[2]
	Quantity (metric tons)	Value (thousands)	(metric tons)	Quantity (metric tons)	Value (thousands)	(metric tons)
Trinidad and Tobago	—	—	2	—	—	6
United Kingdom	27	$48	181	211	$120	1,171
Uruguay	5	4	8	7	6	5
Venezuela	336	241	704	152	128	469
Zimbabwe	—	—	16	—	—	49
Other	5	4	35	91	78	535
Total[3]	41,953	32,613	645,597	39,138	31,679	584,960

[1] Bureau of the Census: Harmonized Code 2440.11.
[2] Bureau of the Census: Harmonized Codes 2840.19, 2840.30, and 2840.20.
[3] Data may not add to totals shown because of independent rounding.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Brazil	—	—	20	$15
Canada	7	$5	38	52
Chile	1,084	492	2,487	1,208
France	7	11	55	36
Germany, Federal Republic of	19	37	4	4
Italy	1,627	1,471	2,841	2,397
Japan	35	82	88	159
Netherlands	65	42	—	—
Taiwan	1	1	—	—
United Kingdom	53	56	25	50
Total	2,898	2,197	5,558	3,921

[1] U.S. Customs declared values.

Source: Bureau of the Census.

Current Research

Traditional ceramics are solids that are stable in temperatures as high as 1,000° C. Advanced ceramics such as boron carbide-aluminum are being developed that are stable at temperatures to 1,500° C or higher. Superconducting material in complex shapes is made by crystallizing material from a previously formed glass. Carefully controlled heating converts this glass to a crystalline ceramic. A combination of metal oxides useful in superconductors can be melted into a glass without adding glass-forming compounds, such as silica or boric oxide, that would dilute the superconductivity of the crystalline ceramic. The boron carbide-aluminum ceramic-metal (cermet) composite combines the toughness of aluminum and the strength of boron carbide ceramic in a single material. Boron carbide powder is sintered at 2,000° C into solid boron carbide sponge and filled with molten aluminum at 1,100° C. The process produces a fully dense, boron carbide-aluminum cermet free of unfilled spaces where cracks could originated.[27]

A plastic composite wheel for cars manufactured using fiberglass-reinforced compounds won the Society of Plastics Engineers' top automotive award. The wheel was developed by Motor Wheel and manufactured by the Goodyear Tire & Rubber Co. The new wheel is 2 to 3 pounds lighter than aluminum wheels and does not corrode.[28]

PPG developed a new fiberglass product for reinforcement applications that creates a surface as smooth as preform molded parts, but at lower costs. The process was available for licensing.[29]

A soccer ball shaped "buckyball" contains 60 carbon atom molecules of the fullerene motif, which are molecules that contain an even number of atoms arranged in closed, hollow cages. Fullerenes have exhibited superconductive properties that are high when compared to other organic superconducting systems. A laser was used to vaporize graphite impregnated with boron nitride and trap the products in macroscopic shapes known as "dopyballs."[30]

Boron 10, a stable isotope of boron, can be concentrated in tumor cells and bombarded with short-range radiation to destroy cancer cells. Developments in boron compounds show marked effectiveness in treating brain tumors. The

TABLE 9

WORLD BORON ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1990, RATED CAPACITY[1]

(Thousand metric tons of boron oxide content)

Country	Capacity
North America: United States	735
South America:	
Argentina	28
Chile	5
Peru[e]	5
Total	38
Europe: U.S.S.R.[e]	41
Asia:	
China[e]	5
Turkey	560
Total	565
World total[2]	1,380

[e] Estimated.
[1] Includes capacity at operating plants as well as plants on standby basis.
[2] Data do not add to total shown because of independent rounding.

TABLE 10

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1986	1987	1988	1989	1990[e]
Argentina	192	185	r270	r261	260
Chile	6	13	32	r131	132
China[e]	27	27	27	27	27
Peru[e]	23	23	e15	e18	18
Turkey	928	r980	r1,231	r1,175	1,200
U.S.S.R.[e]	200	200	200	200	175
United States[2]	1,135	1,256	1,149	[3]1,114	[3]1,094
Total	2,511	r2,684	r2,924	r2,926	2,906

[e] Estimated. [r] Revised.

[1] Tables includes data available through May 14, 1991.

[2] Minerals and compounds sold or used by producers, including both actual mine production and marketable products.

[3] Reported figure.

treatment of malignant melanoma, a pigmented form of skin cancer, is under study. Boron neutron capture therapy may be extended to cancers that respond poorly to current treatment.[31]

OUTLOOK

Production and consumption of boron minerals and compounds have decreased between 1981 and 1990. There are several factors that may lead to misleading outlooks in consumption. One is that production and imports reported in one year may be utilized during a period of years. In addition, environmental concerns may change the demand for boron significantly in a short period. The regulation of fire retardants in products have resulted in changes in boron usage as a fire retardant.

Agriculture

Boron usage in agriculture reached a low in 1982 and has continued to declined. The primary reason was attributed to the decline of the number of farms during the same time period. Farming exports are showing increased strength, and demand for boron usage in agriculture was expected to increase to 20,000 short tons of boron oxide content.

Ceramics and Glass

Boron usage increased during the 1980's, reaching a peak in 1984 that was a 36% increase over that of the prior year. This spike was probably a demand to balance the sharp decline of 1982 of 41%. Ceramics and glass have both faced competition with polymers. In 1990, the U.S. fiberglass industry was reported to be feeling the effects of recessionary pressures. The sagging economy produced a decline in demand for fiberglass reinforcements that was expected to be long term. Fiberglass is closely related to construction and transportation, which continue to be depressed. The fiberglass reinforcements industry that represents 17% of the total composites market forecasts a 6% decline in its construction market for 1991.[32]

Coatings and Plating

Primarily used as a protective coating for steel products and as a glazing on ceramic tiles, usage has experienced a decline. This decline was a result of the demand for polymers that replace many of the coatings and plating uses. Demand was expected to remain at 1990 levels.

Fabricated Metal Products

Boron usage decreased in metal products during the past decade. Many traditional metal products that require soldering now are produced from polymers as one piece. Usage in specialized metal was expected to increase at the rate of 2% per year.

Soaps and Detergents

This usage declined primarily because chlorine bleaches and cold water washes replace boron soap powders. Recent concern for environmental effects of chlorine may reverse the decline. Perborate bleaches have returned to name brand soap products. The usage of boron in soaps and bleaches was expected to increase by 4% per year during the next 5 years.

[1] Weldin, R. D. The California Desert: Protect It or Develop It? Minerals Today. Jan. 1991, pp. 12–17.

[2] Work cited in footnote 1.

[3] Mining World News. BLM Policy Mandates Bonding. V. 2, No. 7, 1990, p. 14.

[4] Farricker, M. FOCUS: Management & Technology: $9M for Maglev Could Mean Billions for Metals. Am. Met. Market, v. 98, No. 19, p. 4.

[5] Industrial Minerals (London). USA: Corona/Avalon Deal Off Over Fort Cady Borate. No. 273, 1990, p. 11.

[6] Thayer, A. M. Advanced Polymer Composites Tailored for Aerospace Use. Chem. & Eng. News, v. 68, No. 30, 1990, pp. 37, 41–44, 48, 50, 52, 55, 56, 60.

[7] Fortune. The Bradley: At Last, a Real Test. V. 123, No. 4, 1991, pp. 50, 54, 56.

[8] Chemical Week. Interox Build Perborate. V. 146, No. 14, 1990, p. 16.

[9] Chemical Marketing Reporter. DuPont Plans to be First in Perborate Monohydrate. V. 238, No. 4, 1990, p. 3.

[10] Hileman, B. Alternative Agriculture. Chem. & Eng. News, v. 68, No. 10, 1990, p. 35.

[11] Wellborn, W. W. The Expanding Role of Synthetic Minerals in Industry. Ind. Miner. (London), No. 283, 1991, pp. 53–54.

[12] Chemical Marketing Reporter. Business Briefs: Boron Maker Changes Name. V. 237, No. 23, 1990, p. 45.

[13] Chemical Week. International Newsletter! V. 146, No. 10, 1990, p. 52.

[14] U.S. Embassy, La Paz, Bolivia. Industrial Outlook Report: Minerals CY 1989. State Dep. Telegram 10443, July 31, 1990, 6 pp.

[15] ———. SPR 4291-Minerals Questionnaire CY-1989. State Dep. Telegram 05179, Apr. 17, 1990, 4 pp.

[16] Mining Journal. Amax's Lithium Withdrawal. V. 315, No. 8096, 1990, pp. 353.

[17] Donoso, R., and C. Theune. Non-Metallic Mining in Chile. Ind. Miner. (London), No. 277, 1990, pp. 63, 65–66, 69, 71.

[18] European Chemical News. AtoChem Converts to Monohydrate. V. 55, No. 1432, 1990, p. 22.

[19] ———. ECN New Project Summary. V. 55, No. 1440, 1990, p. 37.

[20] Work cited in footnote 18.

[21] Chemical & Engineering News. Business Concentrate: Norton Signs Merger Agreement. V. 68, No. 18, 1990, p. 16.

[22] Green Markets. India Moves to Upgrade Micronutrient Units. V. 14, No. 19, 1990, p. 9.

[23] U.S. Embassy, Lima, Peru. SPR 0429, Industrial Outlook Report-Minerals. State Dep. Telegram 06640, May 7, 1990, 10 pp.

[24] Industrial Minerals (London). Venezuela: PPG jv Fibreglass Plant on Stream. No. 271, 1990, p. 15.

[25] Glass Industry (London). Newsletter: Pilkington Has Also Closed. V. 72, No. 5, 1991, p. 6.

[26] Work cited in footnote 24.

[27] Ulrich, D. R. Chemical Processing of Ceramics. Chem. & Eng. News, v. 68, No. 1, 1990, pp. 28–40.

[28] Chemical Week. Plastic Wheel Rolls Out. V. 145,

No. 22, 1989.

[29] Glass Industry (London). PPG Introduces New Roving Products. V. 72, No. 5, 1991, p. 20.

[30] Baum, R. Fulerene Symposium: C 60 Superconductivity Highlighted. Chem. & Eng. News, v. 69, No. 16, 1991, pp. 8-9.

[31] Barth, R. F., A. H. Soloway, and R. G. Fairchild. Boron Neutron Capture Therapy for Cancer. Sci. Am., v. 263, No. 4, 1990, pp. 100-107.

[32] Glass Industry (London). Another Down Year for Fiberglass Reinforced Plastics. V. 72, No. 5, pp. 19, 20.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Boron. Mineral Facts and Problems, 1985.

Boron. Ch. in Mineral Commodity Summaries, annual.

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